Andesite magmas are produced along oceanic arcs where the crust is thin: A new hypothesis

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The straightforward but unexpected relationship presented here relates crustal thickness and magma type in the Izu-Ogasawara (Bonin) Oceanic arc. Volcanoes along the Ogasawara segment of the arc are underlain by thin crust (16-21 km)—in contrast to those along the Izu segment, where the crust is ~35 km thick. Interestingly, andesite magmas are dominant products from the former volcanoes and mostly basaltic lavas erupt from the latter. Moreover, andesite magmas have been similarly dominant in the Oligocene Izu-Ogasawara-Mariana arc, when the arc was immature and their crust must have been thin. Why and how do volcanoes on the thin crust erupt andesite magmas? An introductory petrology textbook might answer this question by suggesting that, under decreasing pressure and hydrous conditions, the liquidus field of forsterite expands relative to that of enstatite, with the result that, at some point, enstatite melts incongruently to produce primary andesite melt. According to the hypothesis presented here, however, rising mantle diapirs stall near the base of the oceanic crust at depths controlled by the thickness of the overlying crust. Where the crust is thin, as along the Ogasawara segment of the arc, pressures are relatively low, and magmas produced in the mantle wedge tend to be andesitic. Where the crust is thick, as along the Izu segment, pressures are greater, and only basaltic magmas tend to be produced. Implications of this hypothesis include the following: (1) A “stockpile” of continental crust (andesitic magma) was produced during the Archean and Proterozoic, when most crust was thin. (2) Most andesite magmas erupted on continental crust could be recycled from “primary” andesite originally produced in oceanic arcs. The rate of continental crust accumulation would therefore have been greatest early in Earth’s history, soon after subduction was initiated.